FIGURE 9. UNIT COSTS OF SPARROW MISSILES IN THOUSANDS OF 1982 DOLLARS

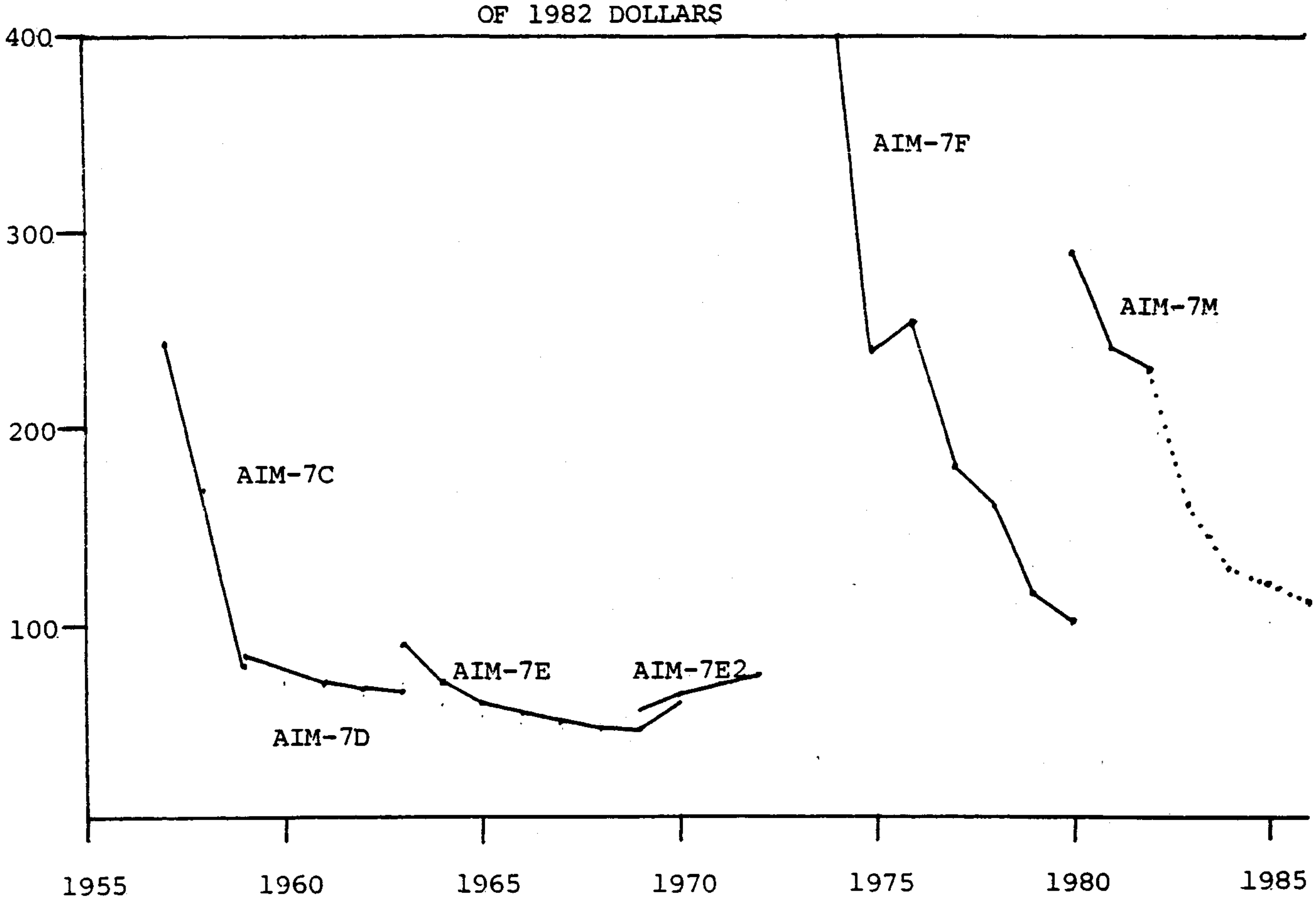
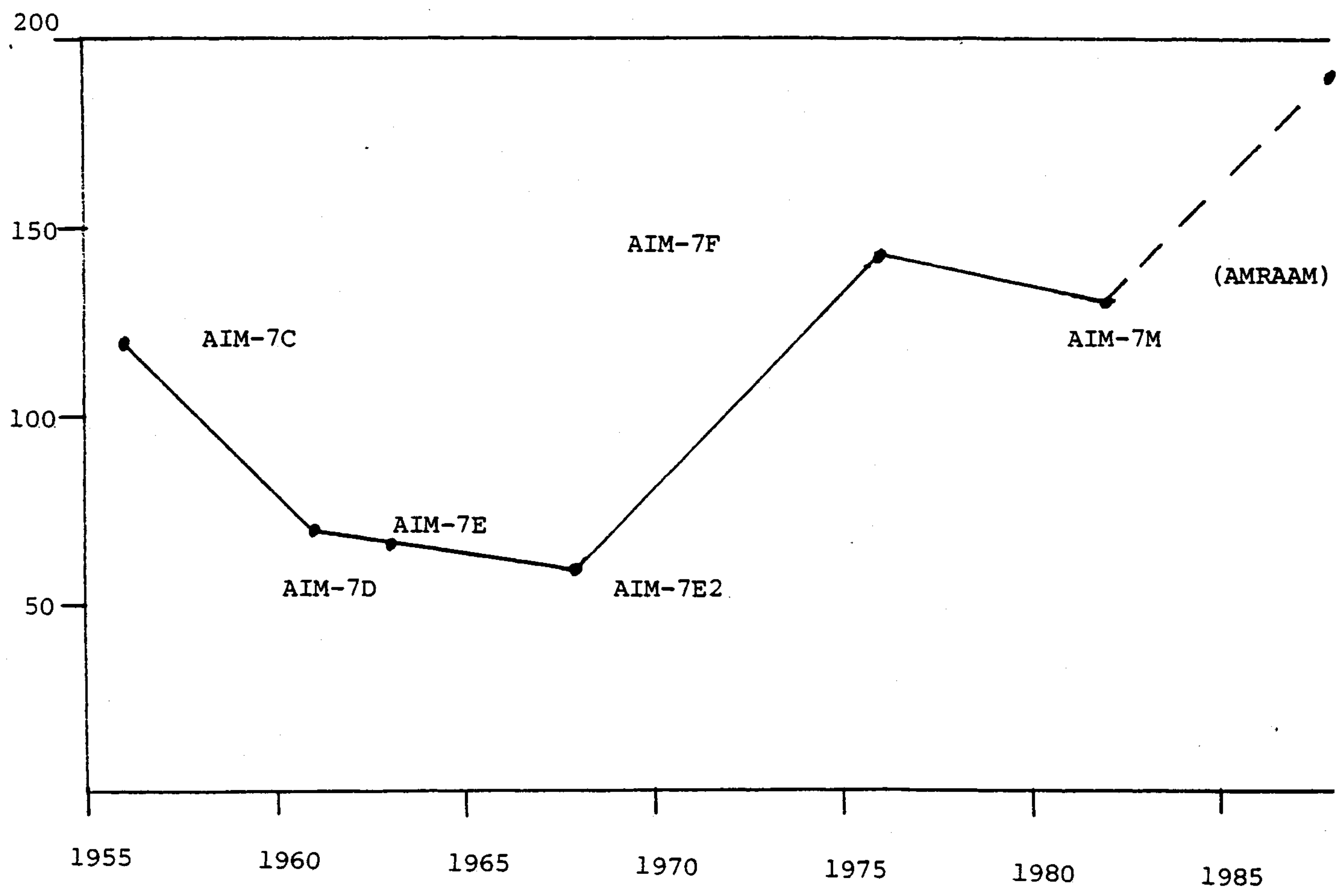


FIGURE 10. AVERAGE UNIT COSTS OF SPARROW MODELS AND AMRAAM

IN THOUSANDS OF1982 DOLLARS



the mid-1970s, the introduction of the Phoenix in 1971, and the doubling of Sparrow unit costs with the introduction of the AIM-7F in the mid-1970s.

This trend does not mean that missiles have only become more expensive over the years. They have also become more capable. In the realities of the budget process, however, the price for increased capability reflected in higher average unit costs has been a large reduction in the overall numbers procured due to limitations on resources allocated.

In replacing a missile with a newer model, the choice of missile design is at least partially based upon "cost/effectiveness"--that is, on cost in relation to some measured value of performance. In theory, a very costly missile could be a better buy than a much less costly one if it is more effective, justifying procurment of smaller numbers. Other factors, however, also limit a choice. Inventories are not based only upon effectiveness. There ought to be at the very least, enough missiles to load up the aircraft, or enough to shoot two at every target aircraft allowing for the fact that the distribution of missiles to units cannot be based upon perfect knowledge of where the enemy will be. For example, the AMRAAM programmed buy of 20,000 exceeds the AIM-7M Sparrow buy by several thousand. Furthermore, while no law limits the budget share allotted to AIMs, in the past it has remained remarkably constrained.

CHAPTER IV. GROWTH IN DEVELOPMENT AND PROCUREMENT COSTS

This chapter examines the growth in the costs of air intercept missile programs for those six systems for which Selected Acquisition Reports (SARs) exist. Cost growth in these systems is compared with cost growth in other SAR systems, and the reasons for growth as identified in the SARs are discussed.

In December 1981, a competitive selection was made of a single contractor to proceed with development and, ultimately, production of AMRAAM. 1/ Concurrently, the program moved from advanced development to full-scale development. Typically, the estimate of program costs--both development and procurement--that is made at about the beginning of full-scale development is called the development estimate. If a SAR is written for the system, it contains the development estimate. Each quarter, an updated SAR is written and sent to the Congress. It contains the development estimate and a current estimate. The current estimate is updated each quarter and the changes documented; the development estimate is never altered. This development estimate then becomes a critical benchmark for measuring future cost growth or "overruns." Cost estimates that precede the development estimate are called planning estimates. These are not reported in the SAR. The first SAR for AMRAAM is anticipated in the fall of 1982. The AMRAAM costs listed in this report are program office estimates formulated in Spring 1982.

This chapter uses the terms "current estimate" and "final estimate," sometimes interchangeably. Final estimate, which is a term not used in the SAR, means the current estimate that appeared in the last SAR for a particular system. For example, the current Sparrow SAR refers only to the AIM-7M; the final estimate for the AIM-7F comes from the last SAR that reported on the AIM-7F.

This chapter deals with the AIM-54A Phoenix, the AIM-7E (including the AIM-7E2), AIM-7F, and AIM-7M Sparrows, and the

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1/ Following the precedent of recent AIM programs, a second procurement source has been selected to competitively produce the missile designed by the prime contractor.

AIM-9L and AIM-9M Sidewinders. Development is complete for all of these programs and procurement is complete for all except the AIM-7M and AIM-9M.

REPORTED COST GROWTH IN AIM-7E, AIM-7F, AIM-7M, AIM-9L, AIM-9M, and AIM-54A

Tables 4 and 5 show the reported growth in the development and unit procurement costs of five Sidewinder and Sparrow models and the AIM-54A Phoenix. The tables show the percent increase of the constant dollar final estimates (or current estimates in the case of the M models) over the development estimates.

TABLE 4. COST GROWTH

System	Development Cost (in millions of 1982 dollars)		Unit Procurement Cost (in thousands of 1982 dollars)	
	Development Estimate	Final or Current Estimate	Development Estimate	Final or Current Estimate
AIM-7E/E2	72	67 a/ b/	67	88 a/ b/
AIM-7F	67	283 a/	108	151 a/
AIM-7M	78	79	112	135
AIM-9L	32	157 a/	47	71 a/
AIM-9M	54	55	69	66
AIM-54A	314	484 a/	630	850 a/ c/
AMRAAM	800 d/		190 d/	

a/ Final estimate.

b/ Selected Acquisition Report was prepared before reporting in constant dollars was instituted. Constant dollar conversion was estimated. However, inflation was low during years in question.

c/ Data taken from December 31, 1977, SAR corrected for presence of AIM-54C.

d/ Planning estimate. SAR not yet available.

TABLE 5. COST GROWTH

System	Milestones: Begin Development	Milestones: IOC a/	Percent Change: Development	Percent Change: Unit Procurement	Percent Change: Unit Procurement for Constant Quantity b/
AIM-7E/E2	1960	1963/68	-5	30	10
AIM-7F c/	1965	1976	320	40	45
AIM-7M	1978	1982	0	20	55
AIM-9L c/	1971	1978	400	50	90
AIM-9M	1976	1982	0	-5	20
AIM-54A c/	1962	1973	55	35	35
Average					43

a/ Initial Operating Capability.

b/ Unit procument costs for constant quantity removes the unit cost distortion caused by amending inventory objectives in the course of the program.

c/ Reflects large technical departure from predecessors.

The unit procurement cost reported in the SAR is the total procurement cost divided by the number of production units. It is affected by both changes in costs and changes in quantity. While the change in the unit procurement cost indicates how well the average unit cost over the entire program conformed to the initial estimates of that cost, the change in unit procurement for constant quantity (that is, the quantity originally specified) shows more directly how well that program was managed, without benefit of an alteration in buy size. For example, the AIM-7E buy size was drastically reduced from that which was originally planned, and the unit cost increased well beyond what would have been the case had the program not been adjusted. The size of the AIM-7F buy was essentially unchanged throughout the program. The others all had buy sizes significantly increased, which reduced overall unit cost growth. Unless otherwise specified, unit cost

growth discussed in the report will be growth in unit cost for constant quantity.

Development Cost Growth

The most striking feature of Tables 4 and 5 is the very large growth in AIM-7F and AIM-9L development costs. Indeed, all those systems that showed cost growth in development programs (AIM-7F, AIM-9L, and AIM-54A) represent substantial technical departures from their predecessors. This is of particular interest because AMRAAM, which will have an active seeker and other features similar to Phoenix, will be quite different from Sparrow.

Chronology lends an important perspective to these anomalous development growths. The AIM-7E/E2 were part of a slowly evolving missile system that began with the AIM-7C (see Chapter II). This is supported by Figure 9, which showed that the yearly unit costs of AIM-7C, D, E, and E2 follow a pattern of unit costs indicative of one missile rather than four successive introductions. It is therefore not surprising that AIM-7E/E2 development costs were well controlled. The AIM-7F, on the other hand, incorporated major technical departures from the preceding models, becoming both a missile for close-in maneuvering air combat (dogfighting) and a medium-range missile that could acquire a target from any direction including above. However, the original estimate of the cost of developing the AIM-7F was about the same as for AIM-7E. The result was a very large development cost increase. After the experience of AIM-7F, the development costs for AIM-7M were well controlled.

Similarly, AIM-9L, developed specifically for dogfighting with an all-aspect seeker, represented a large departure from previous Sidewinders. The development program was seriously underfunded. The succeeding program to develop AIM-9M as an incremental follow-on to the AIM-9L was much more successful in controlling development costs.

The AIM-54A Phoenix development program resulted in an entirely new type of missile, yet its increase in cost--about 50 percent--was much less than the growth in AIM-7F and AIM-9L development programs. This program, however, began with a development cost estimate about five times that of AIM-7F and 10 times that of AIM-9L.

Although AMRAAM will be very different from the AIM-7M it will replace, it is less dissimilar from current missiles than

Phoenix was from the missiles existing when it was developed. Phoenix is much larger and has a much longer range and different guidance mode than any AIM that then existed. AMRAAM will be somewhat smaller than Sparrow with about the same maximum range, and will have the same type of terminal guidance as Phoenix.

The two missiles with very high cost growth may or may not be good predictors for AMRAAM. Both were originally estimated to require development at levels about equal to the less ambitious development programs, well below $100 million in fiscal year 1982 dollars, and eventually grew to several hundred million dollars. The AIM-54A program, originally funded at $300 million in 1982 dollars, grew only 50 percent. AMRAAM is funded at about $800 million and would seem to come closest to the AIM-54A in character when estimated funding and degree of technical change are considered.

These data are inconclusive. One possible interpretation is that costs of developments involving important technical departures are wildly unpredictable. Another is that such developments are all likely to cost several hundred million dollars so that the AMRAAM estimate is likely to be a realistic one. The data provide no statistical basis for choosing one or the other.

Unit Cost Growth

The increases in unit costs for constant quantity are more regularly distributed. All are between 10 percent and 90 percent, with an average of 43 percent and a median of 35 percent to 45 percent. If the 10 percent and 90 percent points are dropped (as a check for consistancy), the average becomes 39 percent and the median is unchanged.

While Table 5 shows no obvious separation on the basis of technical changes, the average cost growth for the three systems representing the greater technical departures from their predecessors (with substantial development cost growth) was twice that of the other three systems (56 percent compared to 28 percent). Similarly, there is no clearcut correlation with chronological sequence. Table 5 shows that Sparrow unit cost increases have grown from AIM-7E to AIM-7F to AIM-7M, while AIM-9M shows a much smaller increase than its predecessor, the AIM-9L. The relation between changes in development costs and changes in unit costs is addressed in a later section.

COMPARISON OF AIM COST GROWTH WITH THAT OF OTHER WEAPONS SYSTEMS

There are currently 44 SAR programs (that is, programs for which Selected Acquisition Reports exist). Figure 11 shows the distribution in growth of the development and unit procurement costs of those systems reported in the September 1981 SARs (updated with data from the March 1982 SARs in those systems in which significant changes occurred in the interval) and indicates where the six AIM systems listed above fall on these distributions. This figure is a "snapshot in time" in the sense that the 44 systems are in various stages of development from initiation of full-scale development to completion of procurement. Not all represent the same level of maturity; some will experience no further cost growth, while others could exhibit significant future growth. Historical evidence leads one to anticipate that, were this data to be compiled when all these programs had reached maturity, the distributions would be shifted toward higher cost growth. 2/

Tactical missile systems reported in the SARs display average growth not significantly different from that of all systems. The distribution of growth in unit procurement costs of the six air intercept missiles is similar to the distribution for all current SARs. The average for these missiles is identical to the average for all SAR systems. Only the AIM-9L exhibits inordinate unit cost growth, roughly twice the average.

Considering the distribution of growth in development costs of air intercept missiles, the average would be a fairly meaningless number. AIM-7F and AIM-9L development cost increases are many times greater than the average for all systems, and well above the growth for any system reported in these SARs. AIM-9M, AIM-7M, and AIM-7E are well below the average, but have the same growth as several systems reported in the SARs.

As noted above, the growth indicated for AIM-7E, AIM-7F, AIM-9L, and AIM-54A comes from the final SARs for those systems

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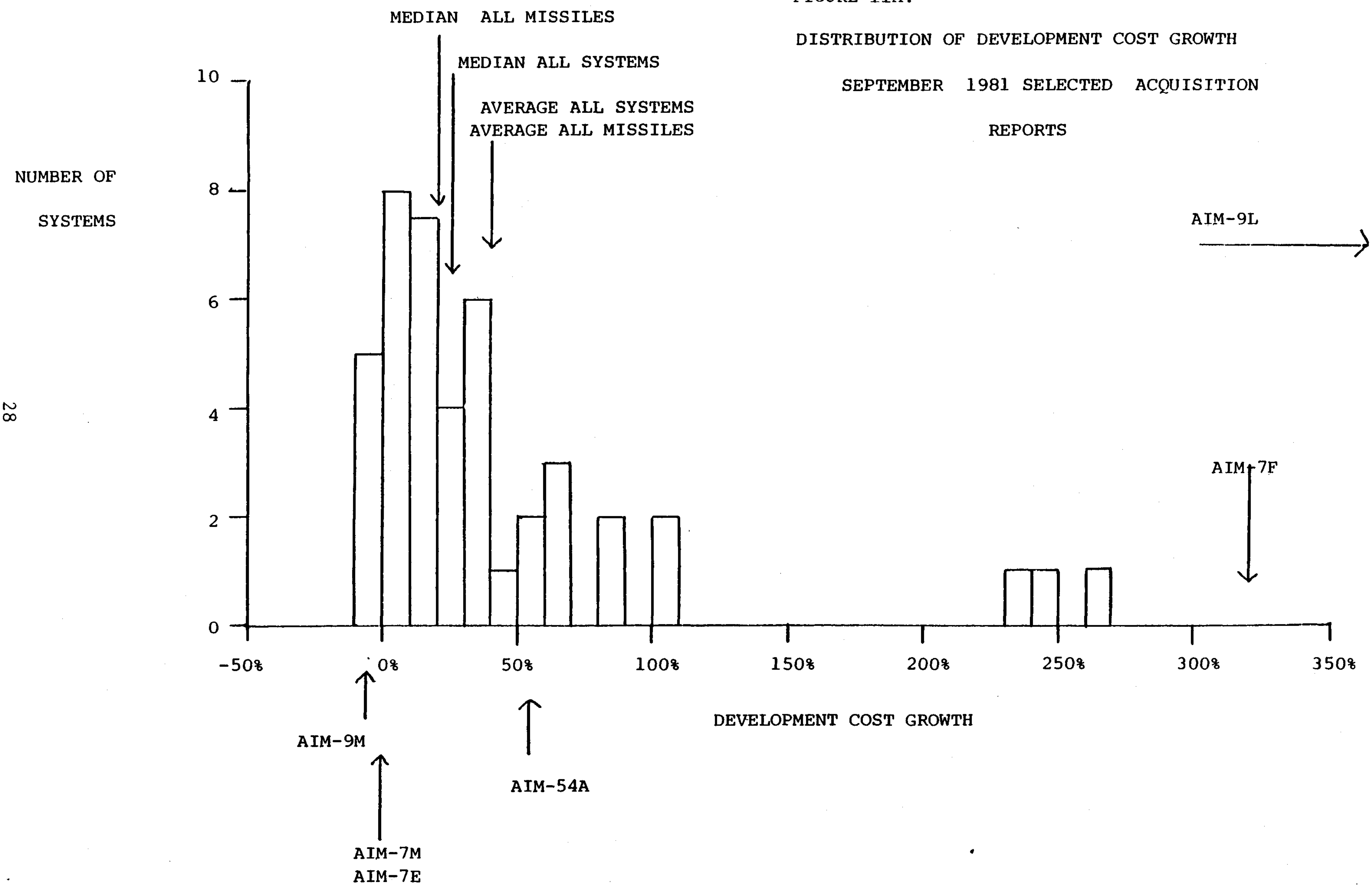
2/ A 1979 Rand Corporation report observed that for 31 SARs examined the total growth (development and procurement corrected for quantity) had a mean value of 1.20 and a median of 1.06, but that mature systems in the sample had an average growth of 1.34 and a median of 1.24. Edmund Dews and others, Acquisition Policy Effectiveness: Department of Defense Experience in the 1970s (October 1979).

FIGURE 11A.

DISTRIBUTION OF DEVELOPMENT COST GROWTH

SEPTEMBER 1981 SELECTED ACQUISITION REPORTS



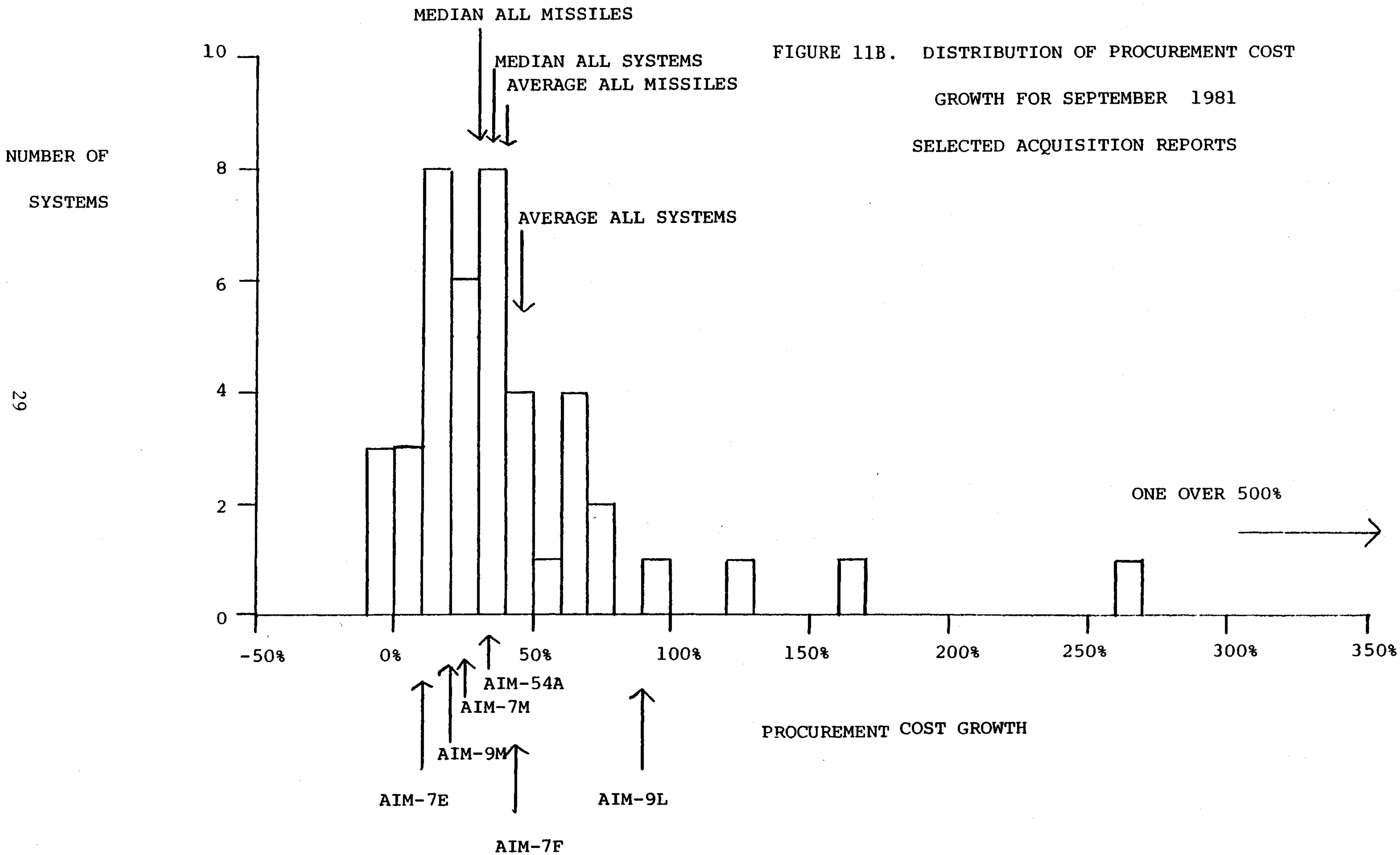


FIGURE 11B. DISTRIBUTION OF PROCUREMENT COST GROWTH FOR SEPTEMBER 1981 SELECTED ACQUISITION REPORTS

(all of which predate September 1981), and can be considered final, reliable numbers. By contrast, AIM-9M and AIM-7M growth figures are the current estimates from the most recent SARs. All of the development funds for these two systems will have been spent prior to fiscal year 1982. Therefore these estimates of development costs and development cost increases are not likely to change and can be considered final. However, procurement, in both cases, has only just begun, with IOC scheduled for late 1982 and early 1983 for AIM-7M and AIM-9M, respectively. A 1980 IDA study determined that there is little cost growth after IOC; most cost growth occurs two to four years after the development estimate. 3/ AIM-7M is three to four years past development estimate; AIM-9M is five to six years beyond development estimate, but both are short of IOC. Similarly, a study by Management Consulting and Research, Inc., reported that the majority of cost growth occurs between development estimate and approval for production (basically the same conclusion). 4/ However, the unit costs of AIM-7F and AIM-9L continued to rise significantly for about one year following IOC. On this basis it is difficult to ascertain whether or not AIM-7M and AIM-9M will sustain further growth in unit costs. Indeed, between September and December 1981, AIM-7M cost growth nearly doubled to its present value, while AIM-9M growth remained essentially unchanged.

CORRELATION OF DEVELOPMENT COST GROWTH WITH UNIT COST GROWTH

Development cost growth provides a simple, relatively unambiguous, observable parameter of a program. If development cost growth can be correlated in a meaningful way with unit cost growth, monitoring development cost growth may provide a useful tool in controlling costs, or at least reducing the risk of large cost increases. In most programs, most of the money is spent in procurement, and not development. For example, in Sidewinder and Sparrow programs, development costs have been only a few

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3/ N.J. Asher and T.F. Maggelet, On Estimating the Cost Growth of Weapons Systems, Institute for Defense Analyses; Cost Analysis Group (June 1980).

4/ Management Consulting and Research, Inc., Analysis of DoD Weapon System Cost Growth Using Selected Acquisition Reports, prepared for Director of Cost and Economic Analysis, U.S. Department of Defense (February 27, 1981).

to 10 or 12 percent of the entire program cost. 5/ Most development funds are spent before large-scale procurement begins, so an estimate of development cost growth is usually available before a large fraction of the money for the program has been spent.

Figure 12 shows the relationship of unit cost growth to development cost growth for the six AIM systems addressed in this chapter. The dashed line is a least squares fit of a straight line to the data. This is discussed in Appendix A. The figure suggests that based only on the six AIM programs discussed here:

- there is no exact relationship between unit cost growth and development cost growth;
- on the average, unit cost growth of about 25 percent is to be expected if development cost growth is low, and low or zero development cost growth is no guarantee of low unit cost growth;
- although the data indicate that higher development cost growth means higher unit cost growth, the correlation of the two is not very strong.

These trends are based on a small data sample, and while suggestive are certainly not definitive. They would be more convincing were they supported by a larger data set. Figure 13 shows a similar plot for all current SARs. The solid line is a least squares fit of a straight line to the data points. The dashed line recreates the dashed line in Figure 12. The figure indicates:

- a precise prediction of unit cost growth from development cost growth would be impossible;
- low development cost growth does not guarantee low unit cost growth;
- higher development cost growth is indicative of higher unit cost growth.

5/ Current estimates for AMRAAM indicate that development will be about 17 percent of the total cost.

FIGURE 12. CORRELLATION OF DEVELOPMENT COST GROWTH WITH UNIT COST GROWTH

FOR SIX AIR INTERCEPT MISSILE MODELS

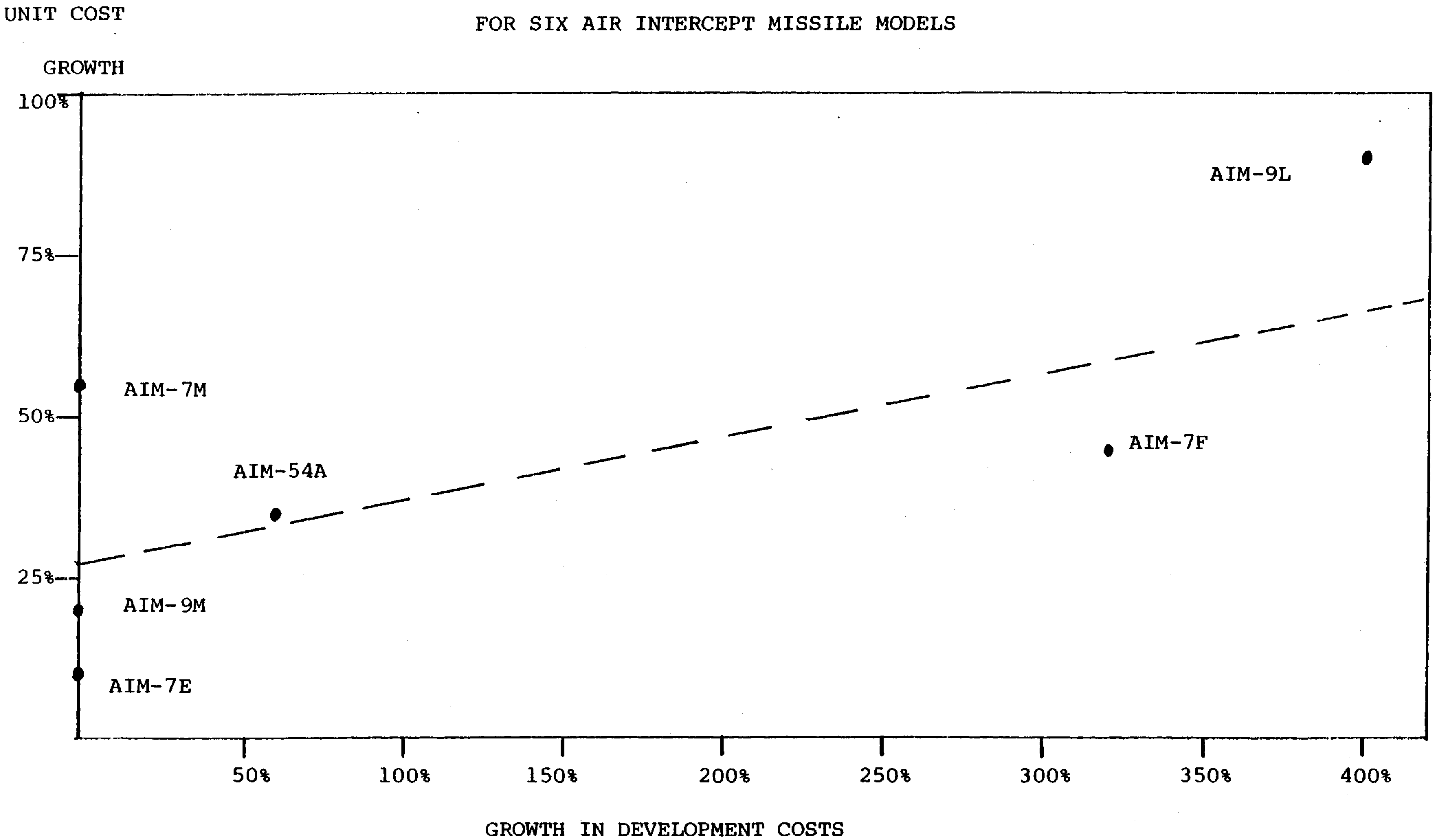
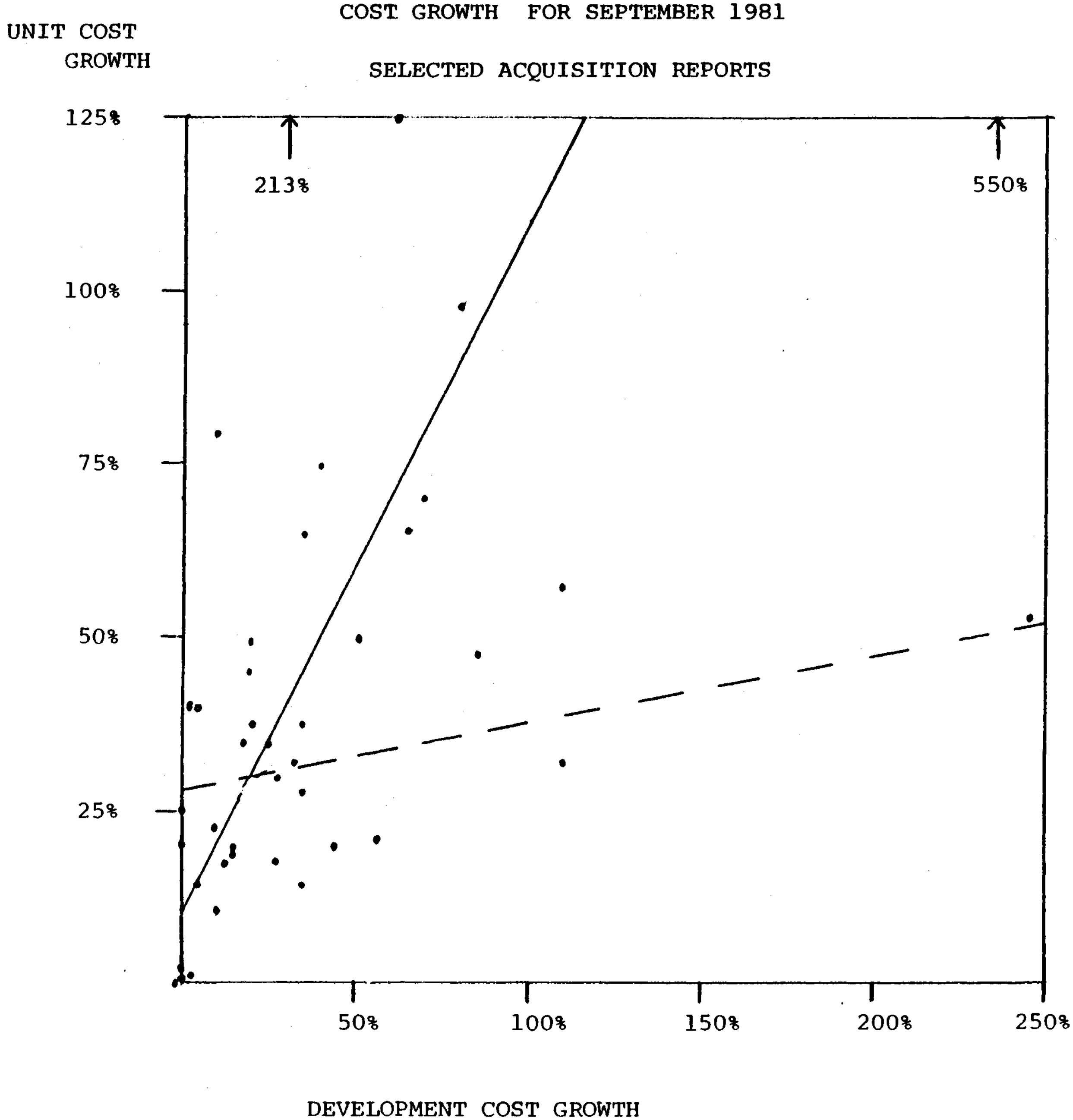


FIGURE 13. COREELATION OF DEVELOPMENT COST GROWTH WITH UNIT COST GROWTH FOR SEPTEMBER 1981

SELECTED ACQUISITION REPORTS



The two figures yield significantly different values of average unit growth for low development growth, and very different trends for the variation of unit growth with development growth. It seems clear that these data cannot be used to predict unit growth from development growth with any certainty. However, using the data in both figures, it is possible to define a value of minimum growth in unit cost as a function of growth in development cost that is consistent with essentially all the data. For development cost growth less than 50 percent, unit cost growth is at least half development cost growth. For development cost growth in excess of 50 percent, minimum unit cost growth appears to be 25 percent plus about one-tenth of the amount by which development cost growth exceeds 50 percent.

The data confirm intuitive expectations. Those factors that operate to produce a low estimate of development cost could be expected to influence a low estimate of procurement cost. Furthermore, the competition for funds provides an incentive to report estimates on the low end of regions of uncertainty.

COST GROWTH BY CATEGORY

The Selected Acquisition Report breaks down cost changes into several categories:

- o Economic--basically unanticipated inflation. Since this study considers only changes in a program reported in constant dollars, economic changes will not apply.
- o Quantity--changes in cost due to changes in the number procured. Since this study looks at cost growth for a constant quantity, this category will also not apply.
- o Schedule--cost changes due to changes in scheduling the program. This can arise from factors internal to the program such as a contractor failing to meet the agreed-upon schedule, or external factors, primarily service, OSD, or Congressional decisions to add or delete funds in any particular year.
- o Engineering--cost changes due to re-engineering.
- o Estimating--correction of a previous estimate. As a program progresses more and more detailed information accrues, and cost estimating becomes a more exact art.

- o Other--reasons not in the above categories, except:
- o Support--changes in costs of required support.

In practice, these categories are not mutually exclusive, and decisions must be made when preparing the SAR as to what categories to assign which changes to. These decisions are guided by precedent and by a requirement to consider the categories in the order listed above, but similar changes appear to be assigned to different categories when several SARs are compared.

Growth in Development Program Costs

AIM-54A, AIM-7F, and AIM-9L provide examples of programs that exhibited noticeable cost growth in development. Phoenix cost growth, 54 percent, was somewhat greater than the average for all recent SAR systems, but the other two exhibited growth in excess of 300 percent, which is very atypical.

In all three cases cost estimating changes are a minor source of change. The AIM-7F and AIM-9L SARs list engineering changes and associated schedule changes as the major sources of growth. Almost all the AIM-54A cost growth reported in the SAR was ascribed to contract cost growth, attributed to increased contractor development costs, and related schedule changes. "Contract cost growth," however, is not one of the currently recognized growth categories. It appears from the description in the SARs that, in all three cases, problems in the development phase required more engineering and other development work which, not unexpectedly, caused the schedule to slip.

In a broad sense, all of these increases could be said to arise from inaccuracy in estimating the cost of the development of the missile at the time of the Development Estimate. However, "estimation" changes are defined as changes due to corrections in preparing an estimate which are not attributable to quantity, engineering, schedule, or support changes. That is, the changes listed as estimation changes are only those that cannot be ascribed to any other cause.

Growth in Unit Costs

AIM-54A Nearly all the growth in Phoenix unit costs is assigned to schedule changes associated with the cancellation of

the F-111B, the originally designated carrier for the Phoenix, and the re-orientation of the program to the F-14A, the current platform. This seems clearly a change beyond the control of the program manager. Removing this source of growth, AIM-54A cost growth has been modest (about 5 percent).

AIM-9L. Roughly one-half of the procurement cost growth exhibited by AIM-9L was attributed to estimation changes associated with redefining costs as the missile went into initial production.

AIM-7F. In this case estimation is a minor change. The majority of growth is assigned to the schedule category for "rescheduling and repricing to best estimate."

AIM-7M. About half of the change is assigned to estimating, and revising procurement quantities in fiscal years 1983 to 1987. The other half is ascribed to repricing as the missile entered production.

AIM-9M. In this case nearly the entire change is assigned to the schedule category, but for "revising the annual procurement profile."

Summary of Unit Cost Growth. From this information, it appears that major parts of unit cost growth in AIM-7F, AIM-7M, and AIM-9M are due to revising the procurement profile. However, in each case, the growth is assigned to a different category. These changes could represent changes dictated from outside the program (that is, by the Navy or Air Force, the Office of the Secretary of Defense, or possibly the Congress) or response to internal factors, or some combination of both.

AIM-9L seems to be a clearcut case of poor estimation of production costs. It was not until the missile actually entered production that the true costs became known, at nearly double the original estimate. About half the growth in AIM-7M appears to be for the same reason. It is not clear what happened in the case of AIM-7F. However, the description implies that this case was similar to that of the AIM-9L; estimates of price and schedules were revised sharply upward as empirical information became available which proved the old estimates inaccurate.

CHAPTER V. IMPLICATIONS FOR AMRAAM

The most obvious lesson from history is that nothing can be said with any certainty concerning a future program by examining the progress of past programs. Nothing obviously constrains future funding patterns to follow past funding patterns or dictates that cost control in future programs will follow that exhibited in the past. If past performance had followed very strong and well defined patterns, a case could be made with some confidence that the prospects were good that those patterns would continue. In reality, however, past performance, while following generally discernible trends, does not display strongly defined behavior. Therefore, almost nothing can be said with any certainty regarding what may happen in the AMRAAM program based upon what has transpired in the past.

Nevertheless, the general trends of the past can be used as clues to bound expectations as to what is likely to occur in the future.

In principle, several factors ought to determine whether or not AMRAAM is procured: the anticipated threat, the performance advantages it offers, and how it compares in "cost/effectiveness" to available alternatives, among others. Ideally, if the system is needed, it ought to be accommodated in the defense budget whatever the cost. A missile that is much more cost/effective than its predecessor although more costly per unit ought to be less costly overall since fewer would be needed to accomplish the same mission.

In reality, cost/effectiveness alone does not determine procurement levels, and the budget may not be elastic enough to accommodate a needed system in sufficient numbers if the cost is too high. The AMRAAM procurement objective exceeds the total AIM-7M buy now planned. This makes sense: more aircraft types will use AMRAAM than will use AIM-7M; both the Navy and the Air Force plan to expand their fighter inventories; and threat improvements will probably add to missile requirements. In the past, the budget share allotted to AIMs, while often fluctuating greatly from year to year, has not changed dramatically on a sustained basis. Extrapolating past trends into the future (and assuming some real growth in defense procurement), it is possible

to envision that there will be sufficient funds available to procure AMRAAM at about the same rate that AIM-7M will be procured assuming that AMRAAM will cost 50 percent more per unit than AIM-7M, as is currently estimated. On the other hand, an assumption of no real increase in AIM funding by the late 1980s may be seen as not inconsistent with historical patterns.

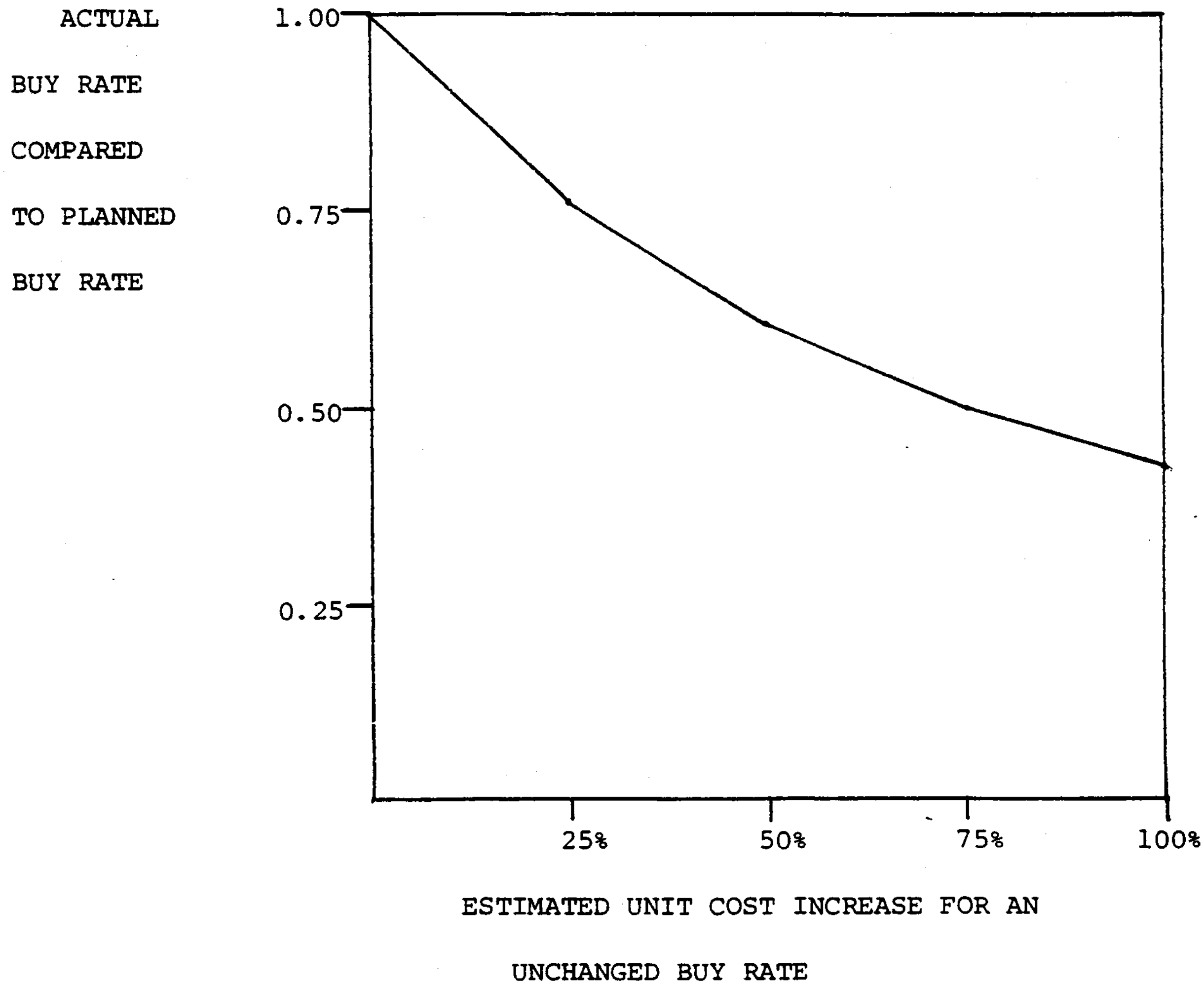
If funding levels are not increased to take account of the higher cost of AMRAAM relative to Sparrow, AMRAAM will be procured at a slower rate than Sparrow has been. There are currently shortfalls in the Sparrow inventory, especially in the inventories of the newer AIM-7F and AIM-7M. 1/ The relatively slow rates at which these missiles have been procured in recent years has caused long delays in reaching inventory objectives. Still lower AMRAAM procurement rates would slow progress toward achieving these objectives still more.

These considerations indicate the importance of cost control in the AMRAAM program. If unit costs exceed current estimates and funding levels are not adjusted accordingly, buy rates will have to be reduced below planned levels. However, reducing buy rates would cause still further cost increases. An estimate of the reduction in buy rate as a function of cost increases is shown in Figure 14. 2/ For example, applying this methodology, a 50 percent increase in the estimated unit cost when combined with a constant funding level would result in a reduction in buy rates to 67 percent of the planned level. However, if the buy rate is reduced, the unit cost is increased still further so that a 50 percent increase actually becomes a 64 percent cost increase and the buy rates are reduced to 60 percent of those originally planned.

1/ Congressional Research Service, Air-to-Air Missile Requirements, Inventories and Alternatives: A Brief Analysis (May 30, 1980); DoD Appropriations for 1981, Hearings before the House Committee on Appropriations, Part 9, pp. 280-308.

2/ The methodology applied to estimate the further cost increases due to buy rate reductions is that described in John C. Bemis, "Three Views of the Impact of Production Rate Changes: III. A Model for Examining the Cost Implications of Production Rates," Concepts: The Journal of Defense Systems Acquisition Management, vol. 4 (Spring 1981), pp. 84-94.

FIGURE 14. EFFECT ON YEARLY BUY RATE OF INCREASES IN ESTIMATED UNIT COST



History provides no clear indication of how much AMRAAM unit costs will actually grow between now and the time it enters production. If AMRAAM follows past patterns, unit costs will grow 10 percent to 90 percent, with 30 percent to 50 percent growth most likely. This analysis ignores the fact that the AMRAAM program office has many years of service experience in developing missiles and other systems to draw upon, and has instituted several management initiatives which could very well keep cost under control. It is interesting to note, however, that the six documented AIM programs do not show a pattern of cost growth decreasing from the earlier programs to the later programs.

In monitoring the AMRAAM program, the Congress may find it useful to observe cost growth closely in the development program. Significant growth in development would be a strong indication of growth to be expected in unit costs. On the other hand, lack of growth in the development program would be no indication of good cost control in procurement.

APPENDIX

APPENDIX A. SHORT STATISTICAL ANALYSIS OF GROWTH IN DEVELOPMENT AND UNIT COSTS

SIX AIR INTERCEPT MISSILE SYSTEMS

This section discusses the correlation of unit cost growth with development cost growth for the six AIM systems shown in Table A-1.

TABLE A-1. COST GROWTH IN AIM SYSTEMS

Missile	Percent Growth in Cost of: Development	Percent Growth in Cost of: Unit for Constant Quantity
AIM-7E/E2	-5	10
AIM-7F	320	45
AIM-7M	0	55
AIM-9L	400	90
AIM-9M	0	20
AIM-54A	55	35

A fundamental concern is whether these data show any correlation between unit cost growth and development cost growth, or are more consistent with these growth categories being two independent variables. If all six values of unit cost growth were found to be consistent with a single probability distribution, it would be an indication that unit growth is independent of development cost growth. Considering only unit cost growth, the four data points other than AIM-7F and AIM-9L have a mean of 30 percent and a standard deviation of 20 (excluding AIM-54A the mean is 28 percent). The probability of a member of this distribution differing from 30 percent by no more than the AIM-7F value does would be about 50 percent. The AIM-7F data are reasonably consistent with the other four; indeed, these five data have a mean of 33 percent

and a standard deviation of 18. However, the probability of a datum which follows this distribution differing from the mean by as much as the AIM-9L datum does is less than 1 percent. Therefore, either the AIM-9L datum is anomalous, or these six data are not consistent with a single distribution. Unfortunately, the absence of further data precludes deciding the case on this basis.

Fitting these data to the linear form:

unit growth = m (development growth) + b

supports the contention that unit growth and development growth are correlated, although weakly. This is illustrated in Table A-2.

All of these fits support a prediction of unit cost growth that is 30 percent plus one-tenth of development cost growth. Although these data are similarly not conclusive, it indicates that the AIM-7F data and not the AIM-9L data may be inconsistent with the rest.

43 SARS

A similar least square fit was performed for 43 September 1981 Selected Acquisition Reports. (One of the 44 SARs showed infinite development cost growth and was discarded.) This resulted in b = .11, m = .99, and R = .61. This indicates that the data are not very consistent with a linear relationship between unit cost growth and development cost growth, and that the best linear fit to these data is very different from the best linear fit to the AIM historical data.

TABLE A-2. LEAST SQUARES FIT OF COST GROWTH DATA

Data Included	b	m	R a/
AIM-7E/E2 AIM-7M AIM-9M AIM-54A	.28	.12	.17
AIM-7E/E2 AIM-7M AIM-9M AIM-54A AIM-7F	.29	.05	.39
AIM-7E/E2 AIM-7M AIM-9M AIM-54A AIM-9L	.28	.16	.85
AIM-7E/E2 AIM-7M AIM-9M AIM-54A AIM-7F AIM-9L	.27	.12	.75

a/ R is the regression correlation coefficient, which has a value $-1 \le R \le +1$. $R = \pm 1$ for a perfect fit.